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(54) **APPARATUS AND METHOD FOR RETRIEVING IMAGE**

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(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/30247*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/30017
USPC 707/769, 770, 780
See application file for complete search history.

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(57) **ABSTRACT**

An image retrieval method includes reading from a first database a first image group mapped to an object as a retrieval target, and extracting an image feature quantity of a plurality of images of the first image group. A second image group mapped to an object as a search key is read from a second database and an image feature quantity of a plurality of images of the second image group is extracted. Similarity is determined between the first image group and the second image group, based on the image feature quantity of the plurality of images of the first image group and the image feature quantity of the plurality of images of the second image group. On an output device, as retrieval results, the plurality of images of the first image group are displayed in order of similarity of the object as the retrieval target based on determined similarity.

15 Claims, 17 Drawing Sheets

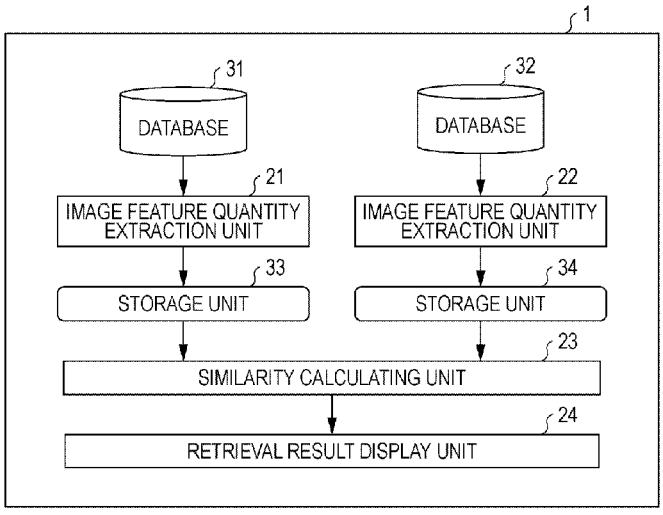

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FIG. 1

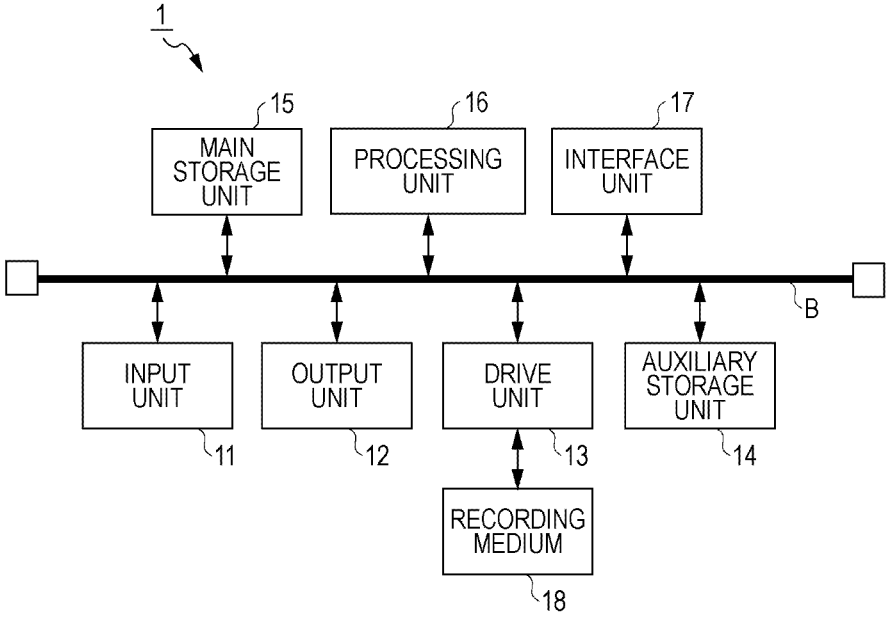

1
15
MAIN STORAGE UNIT
16
PROCESSING UNIT
17
INTERFACE UNIT
B
INPUT UNIT
11
OUTPUT UNIT
12
DRIVE UNIT
13
AUXILIARY STORAGE UNIT
14
RECORDING MEDIUM
18

FIG. 2

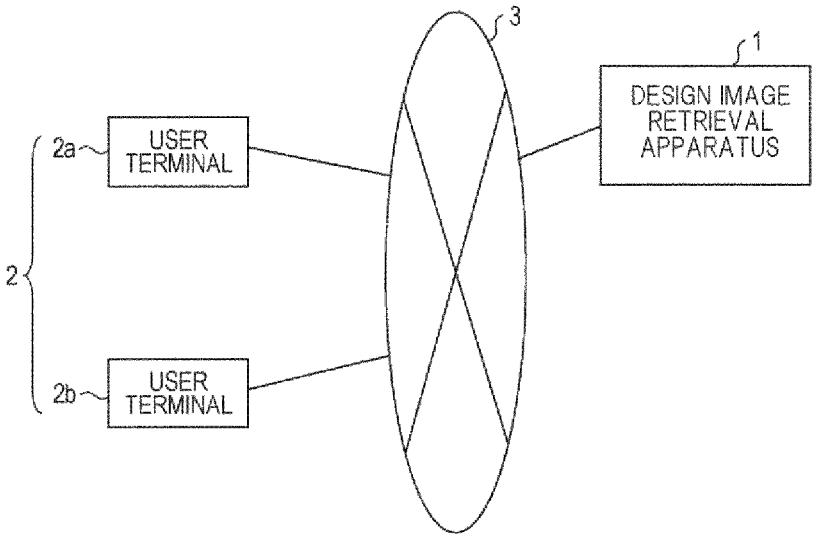

3
1
DESIGN IMAGE RETRIEVAL APPARATUS
2a
USER TERMINAL
2
2b
USER TERMINAL

FIG. 3

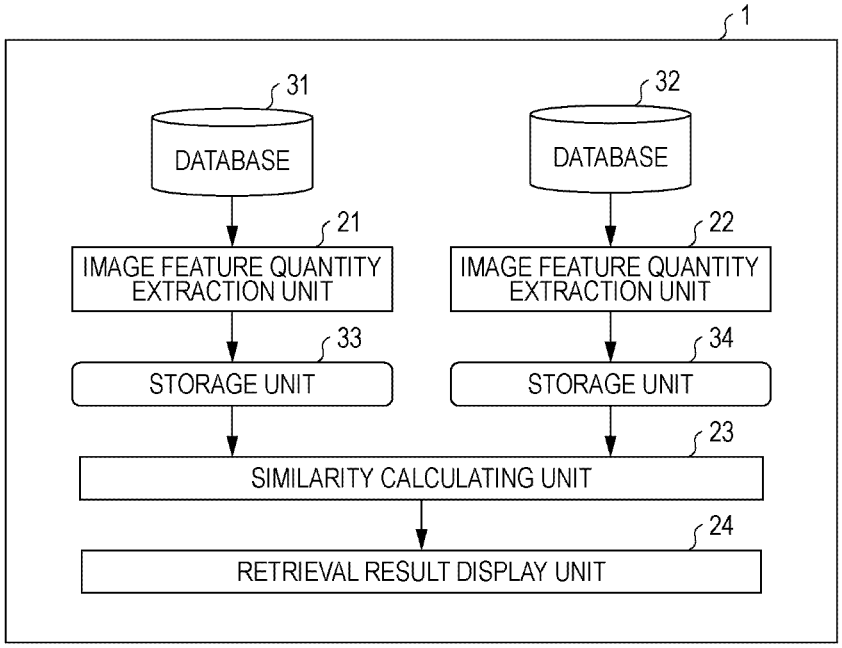

1
31
DATABASE
32
DATABASE
21
IMAGE FEATURE QUANTITY EXTRACTION UNIT
22
IMAGE FEATURE QUANTITY EXTRACTION UNIT
33
STORAGE UNIT
34
STORAGE UNIT
23
SIMILARITY CALCULATING UNIT
24
RETRIEVAL RESULT DISPLAY UNIT

FIG. 4

ID OF TARGET SERVING AS SEARCH KEY	IMAGE FILE NAME	ORIENTATION OF PLANE
Object_000	000_heimen.jpg	PLAN VIEW
Object_000	000_teimen.jpg	BOTTOM VIEW
Object_000	000_syoumen.jpg	FRONT VIEW
Object_000	000_haimen.jpg	REAR VIEW
Object_000	000_migisokumen.jpg	RIGHT-SIDE VIEW
Object_000	000_hidarisokumen.jpg	LEFT-SIDE VIEW
Object_000	000_daihyo.jpg	—
Object_000	000_naname	—

FIG. 5

ID OF TARGET SERVING AS SEARCH KEY	IMAGE FILE NAME	ORIENTATION OF PLANE
Object_#1	#1_heimen.jpg	PLAN VIEW
Object_#1	#1_teimen.jpg	BOTTOM VIEW
Object_#1	#1_syoumen.jpg	FRONT VIEW
Object_#1	#1_haimen.jpg	REAR VIEW
Object_#1	#1_migisokumen.jpg	RIGHT-SIDE VIEW
Object_#1	#1_hidarisokumen.jpg	LEFT-SIDE VIEW
Object_#1	#1_naname.jpg	—
:	:	:
Object_#n	#n_heimen.jpg	PLAN VIEW
Object_#n	#n_teimen.jpg	BOTTOM VIEW
Object_#n	#n_syoumen.jpg	FRONT VIEW
Object_#n	#n_haimen.jpg	REAR VIEW
Object_#n	#n_migisokumen.jpg	RIGHT-SIDE VIEW
Object_#n	#n_hidarisokumen.jpg	LEFT-SIDE VIEW
Object_#n	#n_naname.jpg	—

FIG. 6

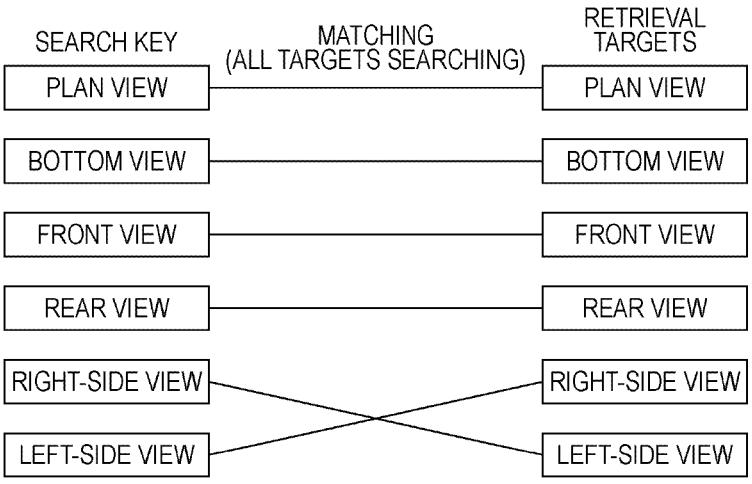

SEARCH KEY
MATCHING
(ALL TARGETS SEARCHING)
RETRIEVAL
TARGETS
PLAN VIEW
PLAN VIEW
BOTTOM VIEW
BOTTOM VIEW
FRONT VIEW
FRONT VIEW
REAR VIEW
REAR VIEW
RIGHT-SIDE VIEW
RIGHT-SIDE VIEW
LEFT-SIDE VIEW
LEFT-SIDE VIEW

FIG. 7

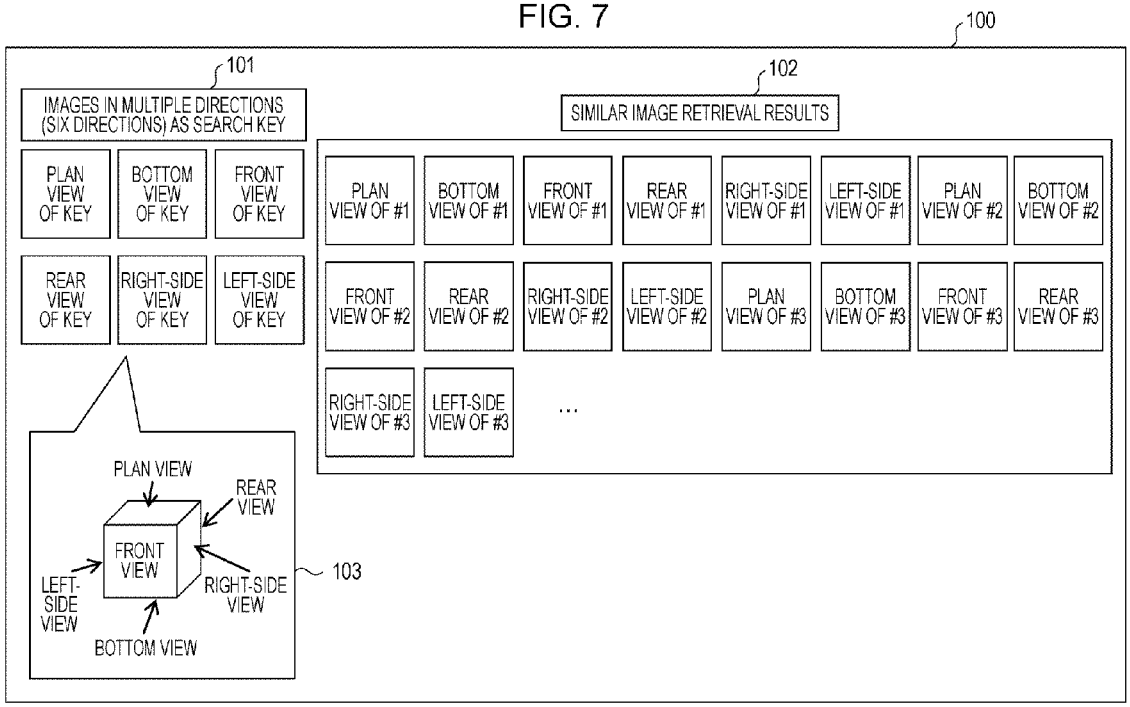

100
101
IMAGES IN MULTIPLE DIRECTIONS (SIX DIRECTIONS) AS SEARCH KEY
PLAN VIEW OF KEY
BOTTOM VIEW OF KEY
FRONT VIEW OF KEY
REAR VIEW OF KEY
RIGHT-SIDE VIEW OF KEY
LEFT-SIDE VIEW OF KEY
102
SIMILAR IMAGE RETRIEVAL RESULTS
PLAN VIEW OF #1
BOTTOM VIEW OF #1
FRONT VIEW OF #1
REAR VIEW OF #1
RIGHT-SIDE VIEW OF #1
LEFT-SIDE VIEW OF #1
PLAN VIEW OF #2
BOTTOM VIEW OF #2
FRONT VIEW OF #2
REAR VIEW OF #2
RIGHT-SIDE VIEW OF #2
LEFT-SIDE VIEW OF #2
PLAN VIEW OF #3
BOTTOM VIEW OF #3
FRONT VIEW OF #3
REAR VIEW OF #3
RIGHT-SIDE VIEW OF #3
LEFT-SIDE VIEW OF #3
...
PLAN VIEW
REAR VIEW
FRONT VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW
103

FIG. 8

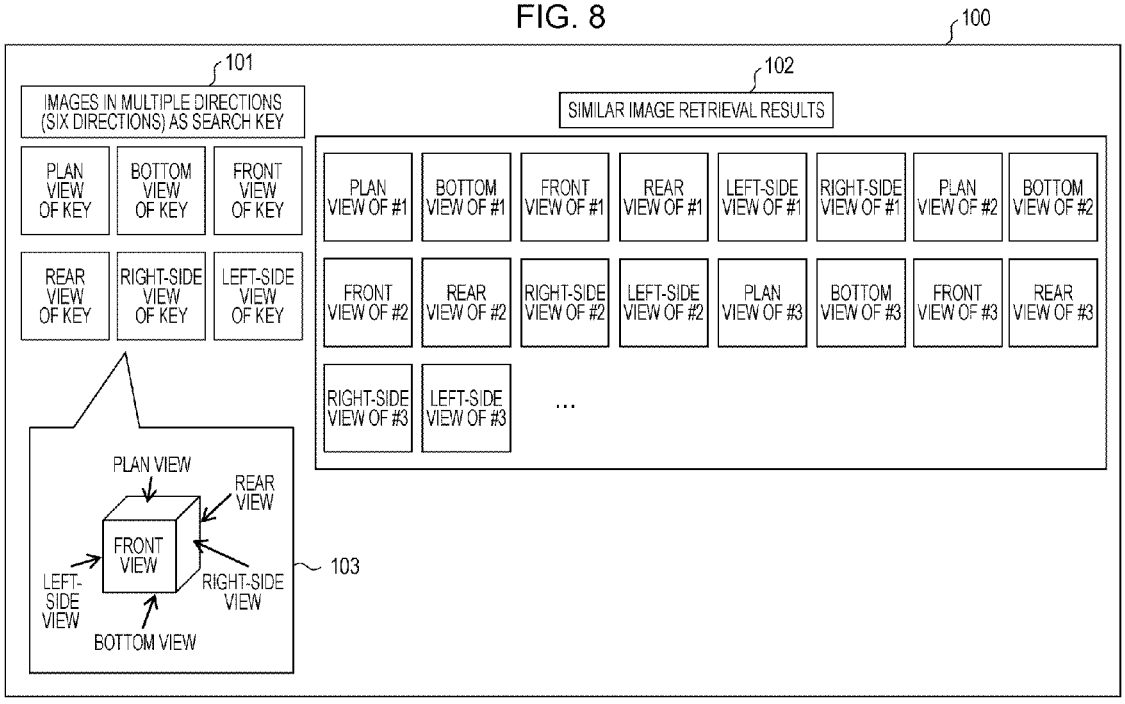

100
101
IMAGES IN MULTIPLE DIRECTIONS (SIX DIRECTIONS) AS SEARCH KEY
PLAN VIEW OF KEY
BOTTOM VIEW OF KEY
FRONT VIEW OF KEY
REAR VIEW OF KEY
RIGHT-SIDE VIEW OF KEY
LEFT-SIDE VIEW OF KEY
102
SIMILAR IMAGE RETRIEVAL RESULTS
PLAN VIEW OF #1
BOTTOM VIEW OF #1
FRONT VIEW OF #1
REAR VIEW OF #1
LEFT-SIDE VIEW OF #1
RIGHT-SIDE VIEW OF #1
PLAN VIEW OF #2
BOTTOM VIEW OF #2
FRONT VIEW OF #2
REAR VIEW OF #2
RIGHT-SIDE VIEW OF #2
LEFT-SIDE VIEW OF #2
PLAN VIEW OF #3
BOTTOM VIEW OF #3
FRONT VIEW OF #3
REAR VIEW OF #3
RIGHT-SIDE VIEW OF #3
LEFT-SIDE VIEW OF #3
...
PLAN VIEW
REAR VIEW
FRONT VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW
103

FIG. 9

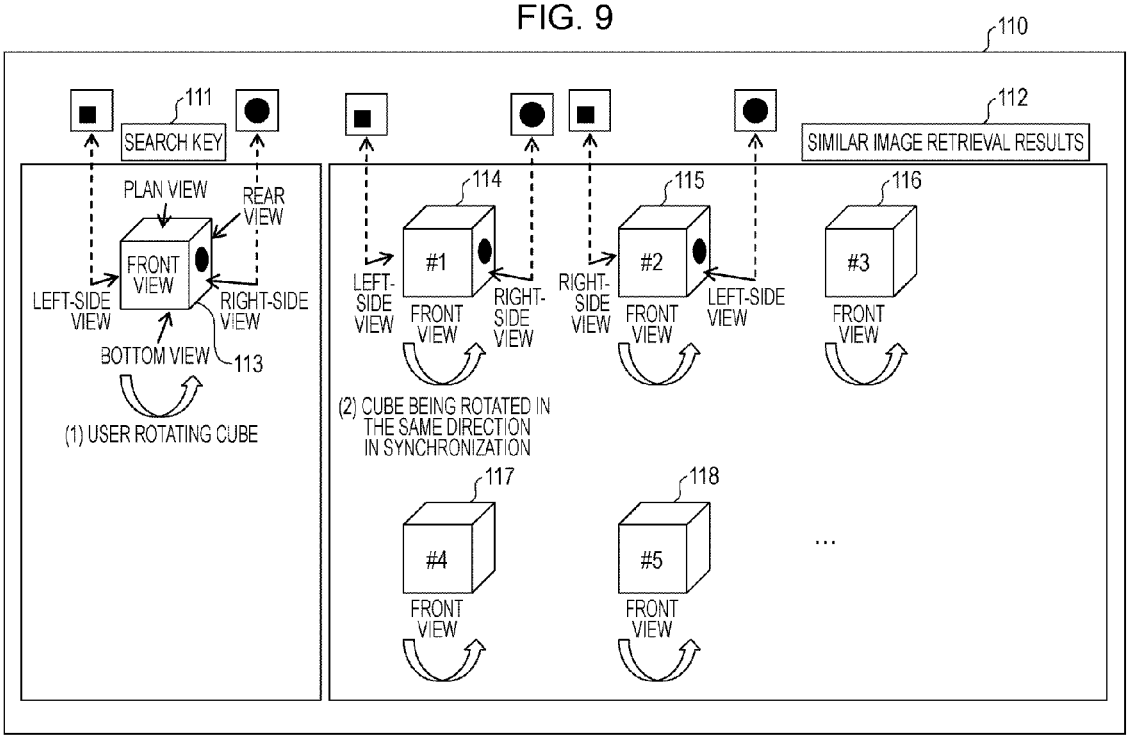

110
111
SEARCH KEY
112
SIMILAR IMAGE RETRIEVAL RESULTS
PLAN VIEW
REAR VIEW
FRONT VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW
113
(1) USER ROTATING CUBE
114
#1
115
#2
116
#3
(2) CUBE BEING ROTATED IN THE SAME DIRECTION IN SYNCHRONIZATION
117
#4
118
#5
...

FIG. 10

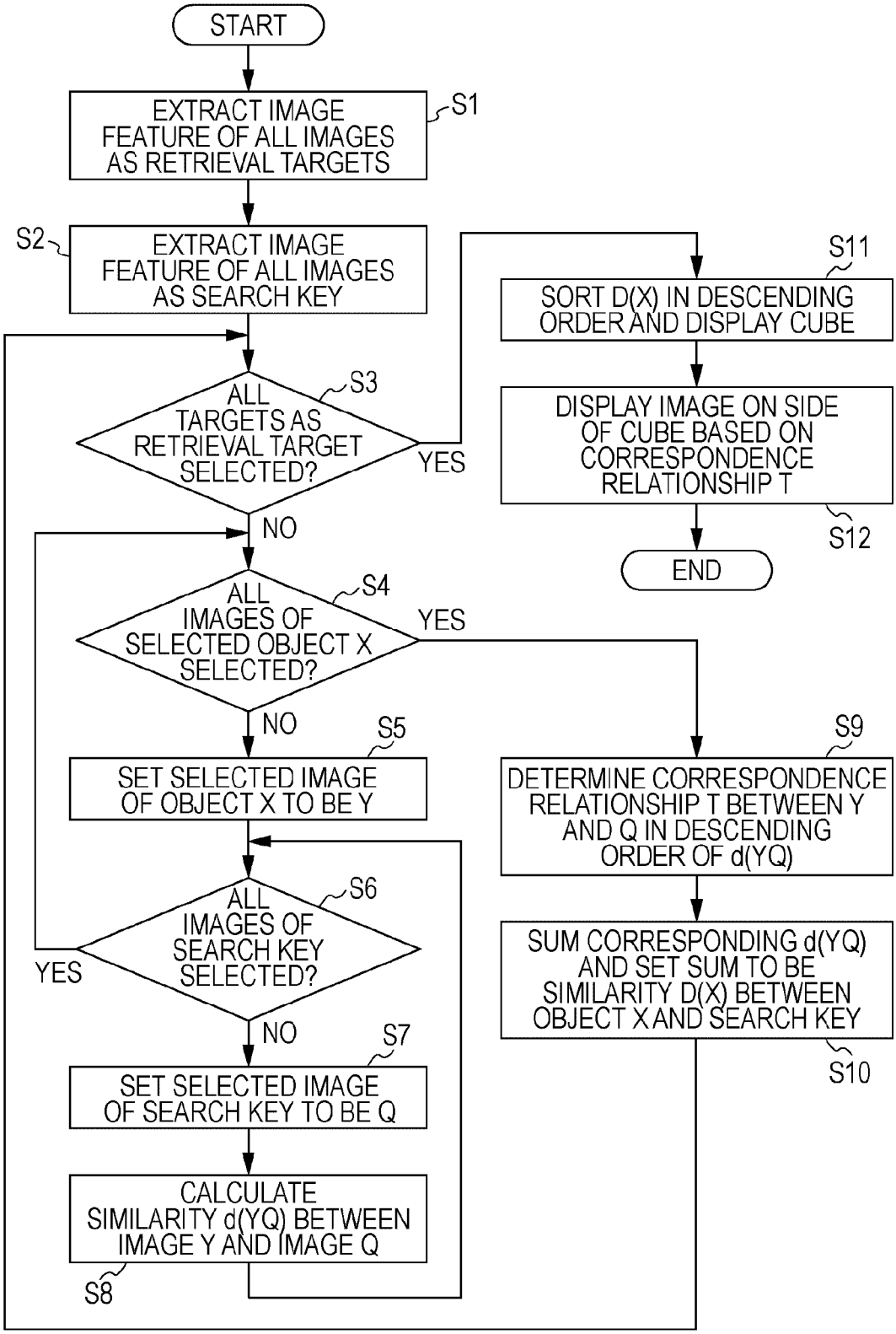

START
EXTRACT IMAGE FEATURE OF ALL IMAGES AS RETRIEVAL TARGETS
S1
EXTRACT IMAGE FEATURE OF ALL IMAGES AS SEARCH KEY
S2
ALL TARGETS AS RETRIEVAL TARGET SELECTED?
S3
YES
NO
ALL IMAGES OF SELECTED OBJECT X SELECTED?
S4
YES
NO
SET SELECTED IMAGE OF OBJECT X TO BE Y
S5
ALL IMAGES OF SEARCH KEY SELECTED?
S6
YES
NO
SET SELECTED IMAGE OF SEARCH KEY TO BE Q
S7
CALCULATE SIMILARITY d(YQ) BETWEEN IMAGE Y AND IMAGE Q
S8
DETERMINE CORRESPONDENCE RELATIONSHIP T BETWEEN Y AND Q IN DESCENDING ORDER OF d(YQ)
S9
SUM CORRESPONDING d(YQ) AND SET SUM TO BE SIMILARITY D(X) BETWEEN OBJECT X AND SEARCH KEY
S10
SORT D(X) IN DESCENDING ORDER AND DISPLAY CUBE
S11
DISPLAY IMAGE ON SIDE OF CUBE BASED ON CORRESPONDENCE RELATIONSHIP T
S12
END

FIG. 11

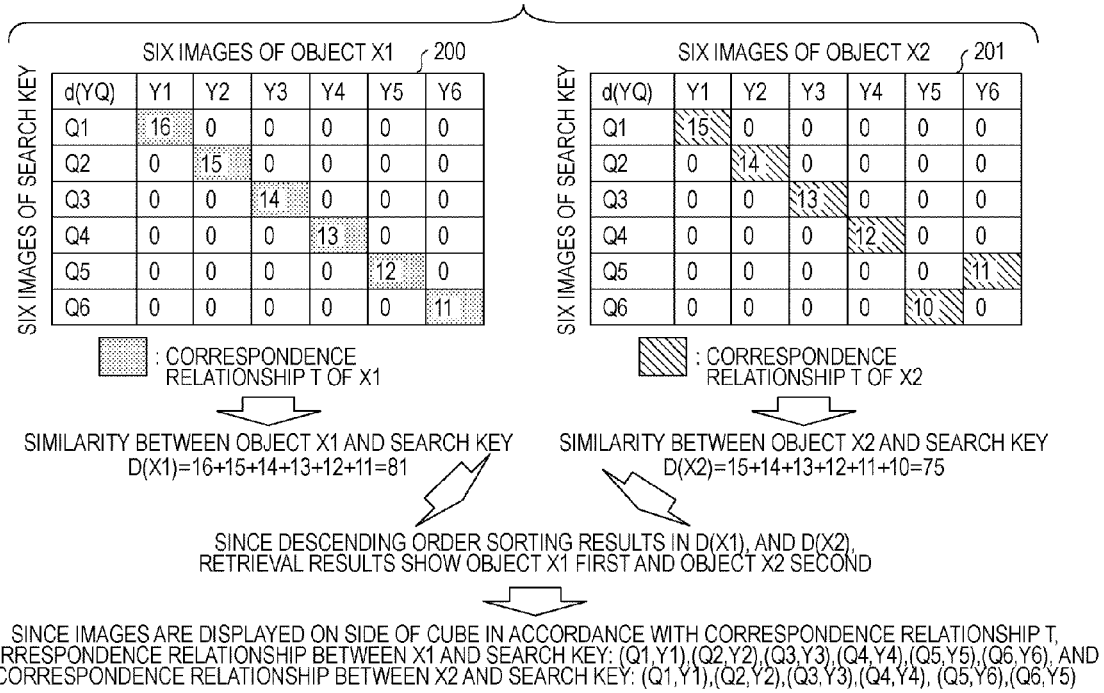

SIX IMAGES OF OBJECT X1
200
SIX IMAGES OF SEARCH KEY
d(YQ) Y1 Y2 Y3 Y4 Y5 Y6
Q1 16 0 0 0 0 0
Q2 0 15 0 0 0 0
Q3 0 0 14 0 0 0
Q4 0 0 0 13 0 0
Q5 0 0 0 0 12 0
Q6 0 0 0 0 0 11
: CORRESPONDENCE RELATIONSHIP T OF X1
SIX IMAGES OF OBJECT X2
201
SIX IMAGES OF SEARCH KEY
d(YQ) Y1 Y2 Y3 Y4 Y5 Y6
Q1 15 0 0 0 0 0
Q2 0 14 0 0 0 0
Q3 0 0 13 0 0 0
Q4 0 0 0 12 0 0
Q5 0 0 0 0 0 11
Q6 0 0 0 0 10 0
: CORRESPONDENCE RELATIONSHIP T OF X2
SIMILARITY BETWEEN OBJECT X1 AND SEARCH KEY
D(X1)=16+15+14+13+12+11=81
SIMILARITY BETWEEN OBJECT X2 AND SEARCH KEY
D(X2)=15+14+13+12+11+10=75
SINCE DESCENDING ORDER SORTING RESULTS IN D(X1), AND D(X2), RETRIEVAL RESULTS SHOW OBJECT X1 FIRST AND OBJECT X2 SECOND
SINCE IMAGES ARE DISPLAYED ON SIDE OF CUBE IN ACCORDANCE WITH CORRESPONDENCE RELATIONSHIP T, CORRESPONDENCE RELATIONSHIP BETWEEN X1 AND SEARCH KEY: (Q1,Y1),(Q2,Y2),(Q3,Y3),(Q4,Y4),(Q5,Y5),(Q6,Y6), AND CORRESPONDENCE RELATIONSHIP BETWEEN X2 AND SEARCH KEY: (Q1,Y1),(Q2,Y2),(Q3,Y3),(Q4,Y4), (Q5,Y6),(Q6,Y5)

FIG. 12

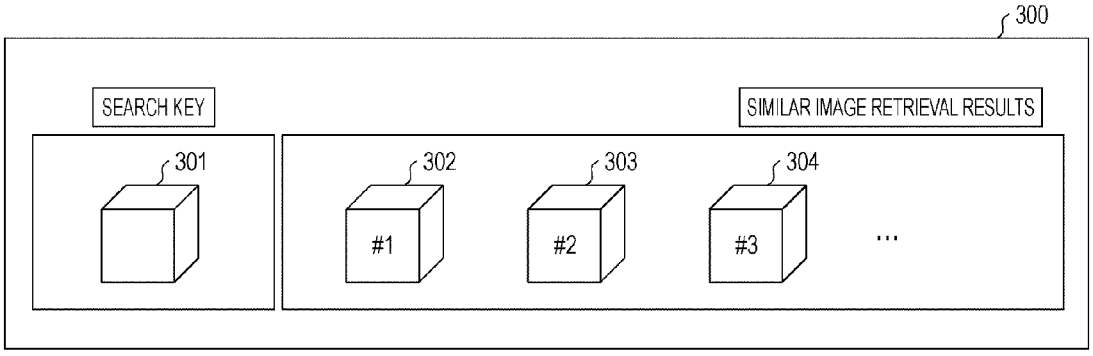

300
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
301
302
303
304
#1
#2
#3
...

FIG. 13

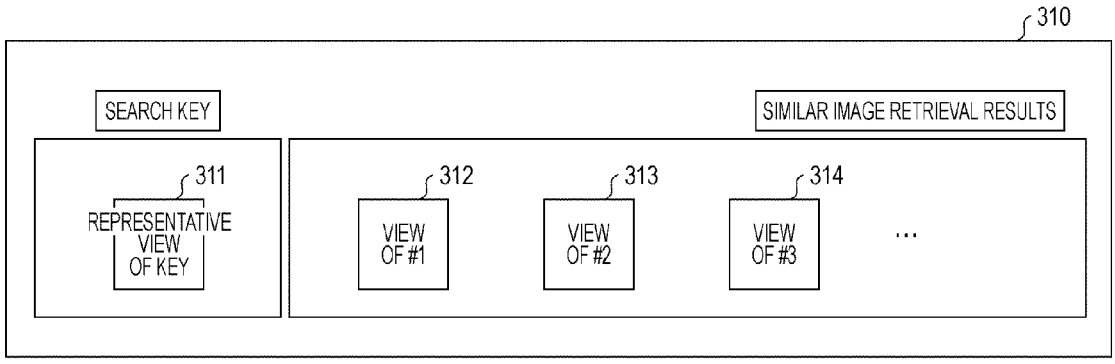

310
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
311
REPRESENTATIVE VIEW OF KEY
312
VIEW OF #1
313
VIEW OF #2
314
VIEW OF #3
...

FIG. 14

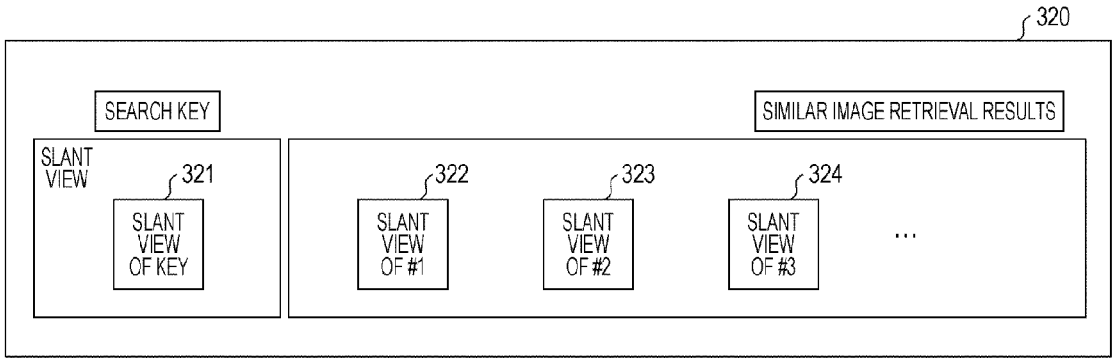

320
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
SLANT VIEW
321
SLANT VIEW OF KEY
322
SLANT VIEW OF #1
323
SLANT VIEW OF #2
324
SLANT VIEW OF #3
...

FIG. 15

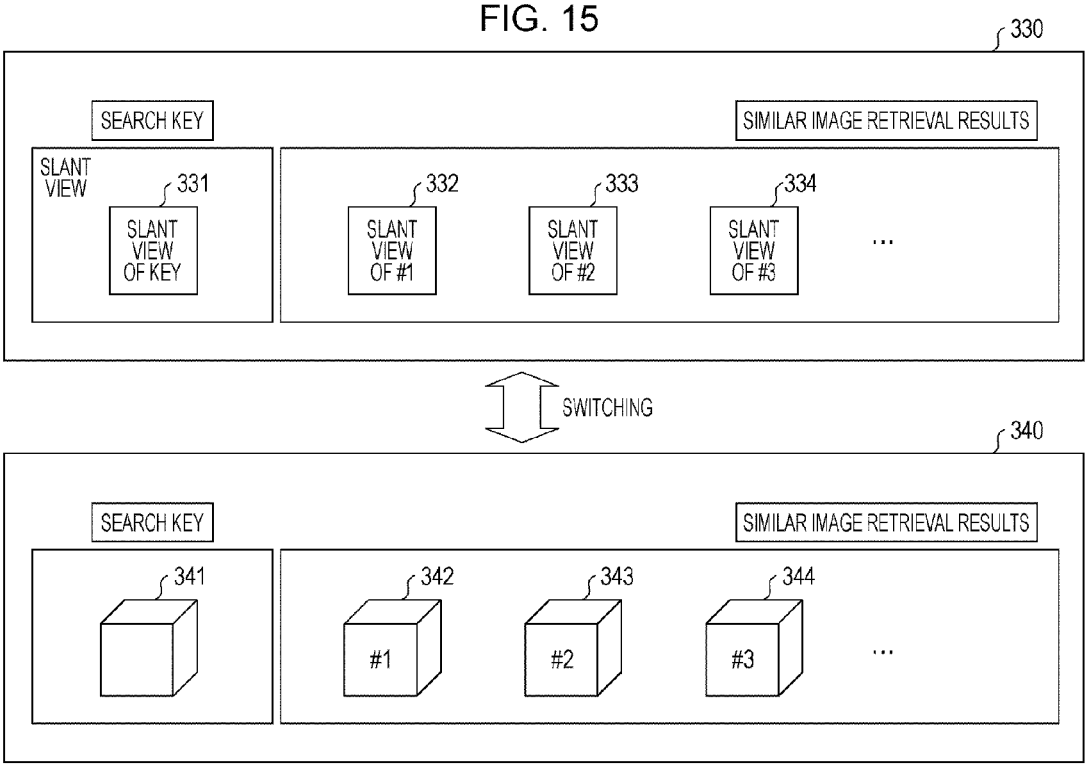

330
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
SLANT VIEW
331
SLANT VIEW OF KEY
332
SLANT VIEW OF #1
333
SLANT VIEW OF #2
334
SLANT VIEW OF #3
...
SWITCHING
340
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
341
342
#1
343
#2
344
#3
...

FIG. 16

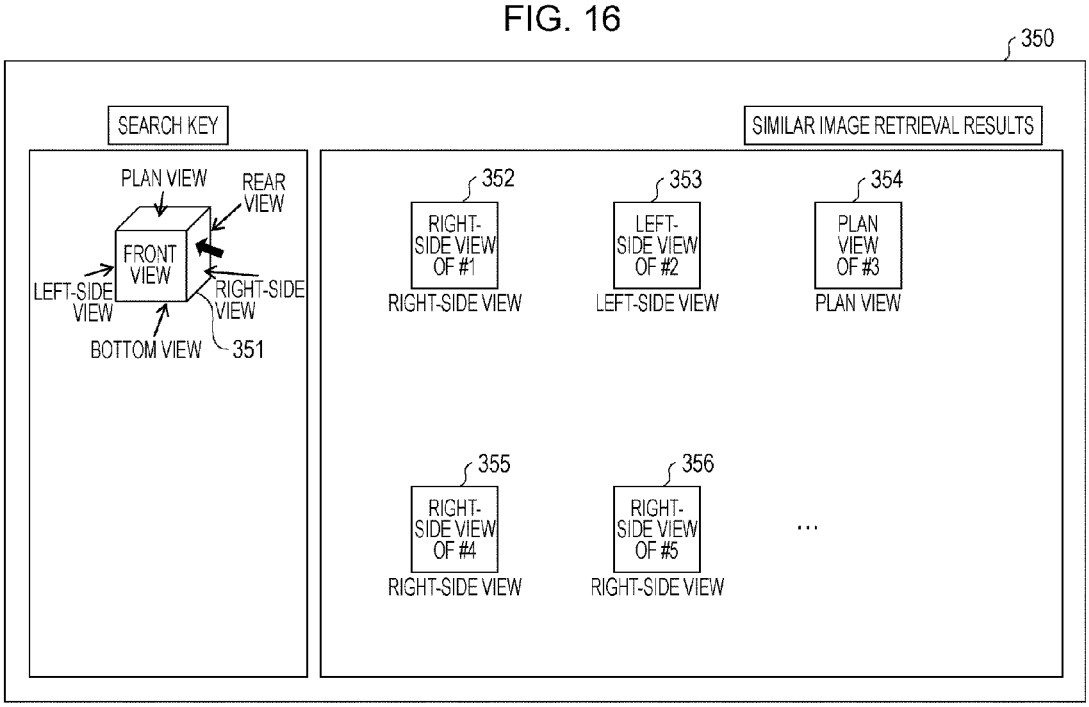
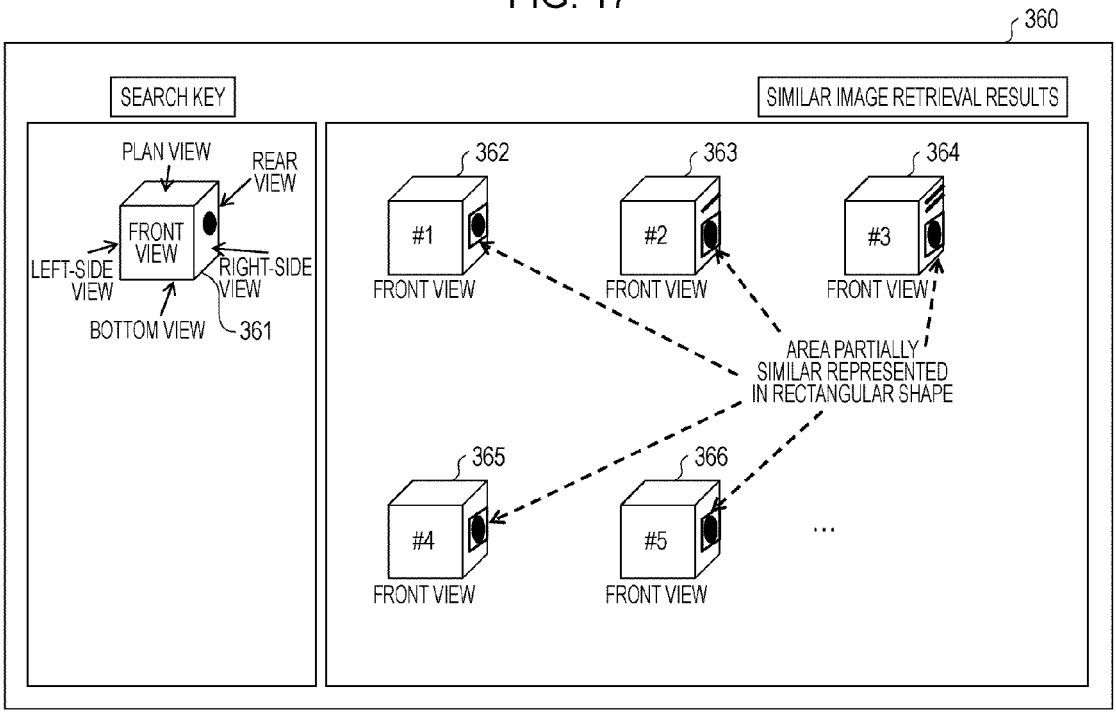

350
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
PLAN VIEW
REAR VIEW
FRONT VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW
351
352
RIGHT-SIDE VIEW OF #1
RIGHT-SIDE VIEW
353
LEFT-SIDE VIEW OF #2
LEFT-SIDE VIEW
354
PLAN VIEW OF #3
PLAN VIEW
355
RIGHT-SIDE VIEW OF #4
RIGHT-SIDE VIEW
356
RIGHT-SIDE VIEW OF #5
RIGHT-SIDE VIEW
...

FIG. 17


360
SEARCH KEY
SIMILAR IMAGE RETRIEVAL RESULTS
PLAN VIEW
REAR VIEW
FRONT VIEW
LEFT-SIDE VIEW
RIGHT-SIDE VIEW
BOTTOM VIEW
361
362
363
364
#1
#2
#3
FRONT VIEW
FRONT VIEW
FRONT VIEW
AREA PARTIALLY SIMILAR REPRESENTED IN RECTANGULAR SHAPE
365
366
#4
#5
FRONT VIEW
FRONT VIEW
...

APPARATUS AND METHOD FOR RETRIEVING IMAGE

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2008-319977, filed on Dec. 16, 2008, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments discussed herein are related to a method and apparatus for retrieving similar objects.

BACKGROUND

Techniques for retrieving similar objects are applied in a variety of fields such as industrial design retrieval in design examinations, product image retrieval in design and manufacture, 3-dimensional computer aided design (3D-CAD), and drawing search in component images. The industrial design retrieval in design examinations is described below.

In the design examination, existing designs similar to a design of a verification target are retrieved to determine design similarity. In the industrial design image retrieval in the design examination, an existing design and a text describing the feature of that existing design are stored on a database (DB) with the design tied to the text. The database is then searched with a keyword as a search key representing the feature of the design as the verification target. The existing design similar to the design as the verification target is thus retrieved.

Japanese Unexamined Patent Application Publication No. 2004-164503 discloses a three-dimensional model retrieval method as a typical image retrieval application. In accordance with the disclosure, a three-dimensional model similarity retrieval is performed with a two-dimensional image as a search key. Japanese Unexamined Patent Application Publication No. 2002-288690 discloses a cubical image display method displaying an image on a cube in the typical image processing.

SUMMARY

According to an aspect of the invention, an image retrieval method of a computer for retrieving similar objects includes reading from a first database an image group mapped to an object as a retrieval target, and extracting an image feature quantity of a plurality of images of the read image group, the first database storing the object as the retrieval target and the image group including the plurality of images resulting from depicting the object as the retrieval target from viewpoints in different directions, with the object as the retrieval target mapped to the image group.

According to the aspect, the image retrieval method further includes reading from a second database an image group mapped to an object as a search key and extracting an image feature quantity of a plurality of images of the read image group, the second database storing the object as the search key and the image group including the plurality of images resulting from depicting the object as the search key from viewpoints in different directions, with the object as the search key mapped to the image group.

According to the aspect, the image retrieval method further includes determining a similarity between the image group mapped to the object as the search key and the image group mapped to the object as the retrieval target, based on the image feature quantity of the plurality of images of the image group mapped to the object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the object as the search key.

According to the aspect, the image retrieval method further includes displaying, on an output device, as retrieval results the plurality of images of the image group mapped to the object as the retrieval target in the order of similarity of the object as the retrieval target based on the determined similarity.

The object and advantages of the invention will be realized and achieved by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates a hardware structure of a design image retrieval apparatus.

FIG. **2** illustrates a design image retrieval system including the design image retrieval apparatus.

FIG. **3** is a block diagram of the design image retrieval apparatus.

FIG. **4** is a data table of a key image group.

FIG. **5** is a data table of retrieval target image groups.

FIG. **6** illustrates an example of correspondence relationship of images as objects for use in retrieval.

FIG. **7** illustrates a screen image of retrieval results.

FIG. **8** illustrates another screen image of retrieval results.

FIG. **9** illustrates a screen image of retrieval results displayed on a cubic diagram.

FIG. **10** is a flowchart illustrating a process of the design image retrieval apparatus.

FIG. **11** illustrates a process of the design image retrieval apparatus.

FIG. **12** illustrates a screen image of retrieval results displayed on a cubic diagram.

FIG. **13** illustrates a screen image of retrieval results displayed on a plan view.

FIG. **14** illustrates a screen image of retrieval results displayed on a representative view.

FIG. **15** illustrates a screen image representing retrieval results in which display switching is performed between the representative view and the cubic view.

FIG. **16** illustrates a screen image of retrieval results in which an image on a side specified by a search key is displayed.

FIG. **17** illustrates a screen image of retrieval results in which portions partially similar are marked by rectangular shapes.

DESCRIPTION OF EMBODIMENTS

An industrial design retrieval performed in a design examination is described below with reference to an embodiment and drawings. The embodiment is described below for exemplary purposes and the invention is not limited to the industrial design retrieval. The invention is applicable not only to the industrial design search but also to other image retrieval applications.

A typical image retrieval method in the design examination, such as a three-dimensional model retrieval using a

two-dimensional image as a search key, may be considered. It is contemplated that six images (on six-pane images) may be used for each of a design as a verification target and an existing design (hereinafter simply referred to as an object). The design as a verification target is used as a search key, and the design (existing design) as a retrieval target is searched and retrieved according to the search key. Since each of the verification target design and the retrieval target design includes six images, some ingenuity may be used in image retrieval as described hereinbelow.

FIG. **1** illustrates a hardware structure of a design image retrieval apparatus **1** according to an embodiment. The design image retrieval apparatus **1** includes input unit **11**, output unit **12**, drive unit **13**, auxiliary storage unit **14**, main storage unit **15**, processing unit **16**, and interface unit **17**, these elements mutually connected to each other via a bus B.

The input unit **11**, which may include a keyboard and/or a mouse, for example, is used to input a variety of signals. The output unit **12**, which may include a display device, for instance, displays a variety of windows and data. The interface unit **17**, which may include a modem and/or a local area network (LAN) card, is used to connect the design image retrieval apparatus **1** to a network such as the Internet.

A design image retrieval program of the embodiment is at least one of the variety of programs controlling the design image retrieval apparatus **1**. The design image retrieval program may be supplied in a recording medium **18** or may be downloaded via the network. The recording medium **18** storing the design image retrieval program may be a recording medium configured to optically or electronically record information, such as a compact disk read-only memory (CD-ROM), a flexible disk, or a magnetooptical disk. The recording medium **18** may alternately or additionally be a semiconductor memory configured to electrically record information, such as a ROM or a flash memory.

Recording medium **18** and the foregoing examples of structures and devices that can be used as the recording medium **18** are examples of a computer-readable storage medium that stores a program causing a computer to perform processes of retrieving similar objects discussed herein, such as the design image retrieval program.

If the recording medium **18** storing the design image retrieval program is loaded onto the drive unit **13**, the design image retrieval program can be installed onto the auxiliary storage unit **14** from the recording medium **18** via the drive unit **13**. Alternately, the design image retrieval program may be downloaded via the network and installed onto the auxiliary storage unit **14** via the interface unit **17**. Thus, a computer-readable storage medium that stores a program causing a computer to perform processes of retrieving similar objects can be remote with respect to design image retrieval apparatus and accessed via the network. The auxiliary storage unit **14** may be a hard disk drive (HDD).

The auxiliary storage unit **14** stores not only the design image retrieval program but also can store related files and/or data. At the startup of the computer, the main storage unit **15** reads the design image retrieval program from the auxiliary storage unit **14** and stores the design image retrieval program on the main storage unit **15**. The processing unit **16** performs a variety of processes to be discussed hereinbelow in accordance with the design image retrieval program stored on the main storage unit **15**.

The design image retrieval apparatus **1** may be used as a standalone apparatus. It is also contemplated that the design image retrieval apparatus **1** can be used in a network system illustrated in FIG. **2**, such as a client-server system (CSS).

FIG. **2** illustrates a design image search system including the design image retrieval apparatus **1**.

In the design image search system of FIG. **2**, the design image retrieval apparatus **1** is connected to at least one user terminal **2** via a network **3** such as the Internet. In FIG. **2**, the at least one user terminal is illustrated as including user terminal **2***a* and user terminal **2***b*, and will hereinafter be referred to as "user terminal **2**." The user terminal **2** is operated by a user who searches for design images. The user terminal **2** transmits a request to the design image retrieval apparatus **1** and receives a response from the design image retrieval apparatus **1**. The design image retrieval apparatus **1** illustrated in FIG. **2** may be identical in structure to the design image retrieval apparatus **1** illustrated in FIG. **1**.

FIG. **3** is a block diagram of the design image retrieval apparatus **1** according to an embodiment. The design image retrieval apparatus **1** includes image feature quantity extraction units **21** and **22**, similarity calculating unit **23**, retrieval result display unit **24**, database **31** storing a key image group, database **32** storing a retrieval target image group, storage unit **33** storing an image feature quantity of a key image, and storage unit **34** storing an image feature quantity of a retrieval target image. The database **31** storing the key image group and the database **32** storing the retrieval target image group may be external to the design image retrieval apparatus **1**.

FIG. **4** is a data table managing key image groups stored on the database **31**. As illustrated in FIG. **4**, the database **31** stores a key image group in six image files. The key image file includes a plurality of images responsive to an object as a search key. More specifically, the key image file includes a plurality of images resulting from depicting the object as the search key from viewpoints in multiple directions.

FIG. **5** is a data table managing retrieval target image groups recorded on the database **32**. As illustrated in FIG. **5**, the database **32** stores n retrieval target image groups in n×6 image files. The retrieval target image group includes a plurality of images responsive to the object as the retrieval target. The plurality of images result from depicting the object as the retrieval target from viewpoints in multiple directions.

Referring to FIG. **3**, the image feature quantity extraction unit **21** extracts an image feature quantity such as color and shape from each image with respect to a key image group, and then records the image feature quantity on the storage unit **33**. Accordingly, the image feature quantity extraction unit **21** is an example of an image feature extracting means for reading from a database **31** an image group mapped to an object as a search key and for extracting an image feature quantity of a plurality of images of the image group. The image feature quantity extraction unit **22** extracts an image feature quantity such as color and shape from each image with reference to a retrieval target image group, and then records the image feature quantity onto the storage unit **34**. Accordingly, the image feature quantity extraction unit **22** is an example of an image feature extracting means for reading from the database **32** an image group mapped to an object as a retrieval target and for extracting an image feature quantity of a plurality of images of the image group.

An image feature quantity of color may be a "color histogram" representing the frequency of occurrence of color at each pixel. An image feature quantity of shape may be a "grid Fourier feature quantity". In this case, an image is partitioned into concentric circular regions, and the ratio of black pixels within each concentric region is represented by the grid Fourier feature quantity.

The image feature quantities of color and shape are multi-dimensional information and are thus represented using vectors. In some embodiments, the image feature quantity

extraction units **21** and **22** may trim a background portion of an image in response to a user's manual operation, or may activate an automatic background removal operation. An image feature quantity is thus extracted from an area other than the background.

An example of a "grid Fourier feature quantity" that is suitable for use with embodiments discussed herein is detailed in a paper entitled "A shape-based part retrieval method for mechanical assembly drawings," contributed by T. Baba, R. Liu (FRDC), S. Endo, S. Shiitani, Y. Uehara, D. Masumoto, and S. Nagata, Technical Report of IEICE, PRMU 2004-225, pp. 79-84, March 2005, which is incorporated herein by reference.

The image feature quantity extraction units **21** and **22** may use a graph-based feature quantity for partial retrieval. An example of a graph-based feature quantity that is suitable for use with embodiments discussed herein is disclosed in a paper entitled "Similarity-based Partial Image Retrieval System for Engineering Drawings," contributed by T. Baba, R. Liu (FRDC), S. Endo, S. Shiitani, Y. Uehara, D. Masumoto, and S. Nagata, Proc. of Seventh IEEE International Symposium on Multimedia (ISM2005), pp. 303-309, Dec. 14, 2005, which is incorporated herein by reference.

In graph representation, a line segment representing the outline of an object is referred to as a node, and a closeness between line segments is referred to as an edge. Objects constructed of line segments having a similar structure, regardless of the presence of slight noise or a slight difference in the lengths of the line segments, may be retrieved as similar objects in graph representation.

The similarity calculating unit **23** calculates a similarity between an object as a retrieval target and an object as a search key, based on image feature quantities of images responsive to the object as the retrieval target and the object as the search key. Accordingly, the similarity calculating unit **23** is an example of a similarity calculating means for calculating a similarity between an image group mapped to the object as a search key and an image group mapped to the object as the retrieval target. According to an embodiment, the image feature quantity extraction units **21** and **22** represent the images by the feature quantities in vector, and the similarity calculating unit **23** calculates the similarity between the images using Euclidean distance. The shorter the Euclidean distance, the higher the similarity.

Several different methods are available to determine similarity between objects. In one method, the mean value of the similarities between images is adopted as a similarity of the objects. More specifically, referring to FIG. **6**, the image similarity is determined on all combinations of the images of the objects, and a correspondence relationship of the images providing the maximum sum of the similarities is determined.

FIG. **6** illustrates the correspondence relationship of the images of the objects used in retrieval. Referring to FIG. **6**, six images depicted in multiple (six) directions (plan view, bottom view, front view, rear view, right-side view, and left-side view) are used for one object. Corresponding images of the objects are line connected to each other in FIG. **6**.

As illustrated in FIG. **6**, for example, the right-side view of the object as the search key corresponds to the left-side view of the object as the retrieval target. The left-side view of the object as the search key corresponds to the right-side view of the object as the retrieval target. In this and other examples, the similarity calculating unit **23** calculates the mean value of the similarities between the six pairs of lined-connected images, and thus sets the mean value as the similarity of the objects.

In a second method of determining the similarity between the objects, the maximum one of the similarities between the corresponding images of the objects is set to be the similarity of the objects. Referring to FIG. **6**, the similarities between the images in all combinations of the images are determined and the correspondence relationship of the images providing the maximum sum of similarities is determined. In this and other examples, the similarity calculating unit **23** sets to be the similarity between the objects the maximum one of the similarities between the line-connected images in the six pairs.

As illustrated in FIG. **7**, the retrieval result display unit **24** arranges, as the retrieval results, the images of the object as the retrieval target similar to the object as the search key in the order of similarity, and displays the images of the object as the retrieval target together with the images of the object as the search key. Accordingly, the retrieval result display unit **24** is an example of a retrieval result displaying means for displaying, on an output device, as retrieval results the images of an image group mapped to the object as the retrieval target in the order of similarity of the object as the retrieval target based on the similarity calculated by the similarity calculating unit.

FIG. **7** illustrates a screen image representing the retrieval results. The retrieval result display unit **24** displays a retrieval result display screen **100** as illustrated in FIG. **7**. The retrieval result display screen **100** includes six images of an object **103** (such as an industrial design of a cell phone, for example) as a search key (illustrated at element **101**) depicted in six directions (plan view, bottom view, front view, rear view, right-side view, and left-side view), and similar image retrieval results **102** in which images (plan view, bottom view, front view, rear view, right-side view, and left-side view) of objects as retrieval targets similar to the object **103** as the search key are arranged in the order of similarity.

Referring to FIG. **7**, the retrieval result display unit **24** displays the images of the objects as the retrieval targets that are similar to the object **103** as the search key in the order of the plan view, the bottom view, the front view, the rear view, the right-side view, and the left-side view on the retrieval result display screen **100**. In this case, the images of the objects as the retrieval targets that are similar to the object **103** as the search key are rearranged and displayed based on the correspondence relationship of the images maximizing the sum of the similarities.

FIG. **8** illustrates another screen image of the retrieval results. In the case of FIG. **6**, the right-side view of the object **103** as the search key corresponds to the left-side view of the object as the retrieval target. The left-side view of the object as the search key corresponds to the right-side view of the object as the retrieval target. Referring to FIG. **8**, the retrieval result display unit **24** rearranges a "left-side view of #**1**" and a "right-side view of #**1**" on the similar image retrieval results **102** and displays the re-arranged views on the retrieval result display screen **100**.

The retrieval result represented in a cubic diagram may be more intelligible to the user than the retrieval result represented in the six-pane views on the retrieval result display screen **100** of FIGS. **7** and **8**. For instance, as illustrated in FIG. **9**, the retrieval result display unit **24** can display, in a cubic diagram on a retrieval result display screen **110**, images of an object **113** as a search key **111** and images of objects **114-118** as retrieval targets that are similar to the object **113** as the search key.

FIG. **9** illustrates an example of screen image representing the retrieval results in cubic diagrams. The retrieval result display unit **24** displays the object **113** as a search key **111** in a cubic diagram while also displaying, in a cubic diagram on

the retrieval result display screen **110**, similar image retrieval results **112** including objects **114-118** as the retrieval targets that are similar to the object **113** as the search key **111**. The retrieval result display unit **24** displays various planar images of the objects **113-118** as cubes in a virtual three-dimensional space in the example of FIG. **9**. The retrieval result display unit **24** produces cubic diagrams of the objects **113-118** by displaying the six images for each object **113-118** on the respective sides of each corresponding cube. In the cubic diagrams of the objects **113-118**, the object **113** as the search key **111** and the objects **114-118** as the retrieval targets that are similar to the object **113** as the search key **111** may be produced by different creators and thus depicted as images oriented in different directions.

The retrieval result display unit **24** may rearrange the images of the objects **114-118** as the retrieval targets that are similar to the object **113** as the search key **111** based on the correspondence relationship of the images maximizing the sum of the similarities illustrated in FIG. **6**. The retrieval result display unit **24** then displays the rearranged images of the objects **114-118** on the retrieval result display screen **110**.

Referring to FIG. **9**, the right-side view of the object **113** as the search key **111** corresponds to the left-side view of the object **115** as a retrieval target. The left-side view of the object **113** as the search key **111** corresponds to the right-side view of the object **115** as the retrieval target. The retrieval result display unit **24** thus rearranges the "left-side view of #**2**" and the "right-side view of #**2**" on the similar image retrieval results **112** in reverse order and then displays the rearranged images on the retrieval result display screen **110** as depicted in FIG. **9**.

The object **115** on the similar image retrieval results **112** illustrated in FIG. **9** is depicted in a laterally reversed position with respect to the object **113** as the search key **111**. The retrieval result display unit **24** thus interchanges the right-side view of the object **115** as the retrieval target with the left-side view of the object **115** as the retrieval target in accordance with the image similarity to comply with the object **113** as the search key **111**. The retrieval result display unit **24** then displays the rearranged images so that the images having a higher similarity are arranged on the same sides.

In some embodiments, the retrieval result display unit **24** can then change the orientation relationship of the cube on the retrieval result display screen **110** in response to a user's manual operation. The retrieval result display unit **24** can also display the image displayed on the front (such as the front view) in a front-down fashion on the objects **114-118** on the similar image retrieval results **112**.

When the user rotates the object **113** as the search key **111** on the retrieval result display screen **110**, the retrieval result display unit **24** allows the objects **114-118** to rotate on the similar image retrieval results **112** in synchronization with and in the same direction as the object **113** as the search key **111**. The user can freely rotate the object **113** as the search key **111** and the objects **114-118** on the similar image retrieval results **112** and verify the rotation results.

In order to display the retrieval result display screen **110** as illustrated in FIG. **9**, the retrieval result display unit **24** represents by polyhedrons the object **113** as the search key **111** and the objects **114-118** as the retrieval targets in the order of similarity, and attaches and displays the images on the respective sides of the polyhedrons in correspondence to the object **113** as the search key **111**. If an image orientation label is attached as attribute information to each image, the retrieval result display unit **24** displays the image orientation labels of images in front (such as a front view) just below the respective object **113** as the search key **111** and respective objects **114-118** as the retrieval targets.

A process of the design image retrieval apparatus **1** is described below with reference to a flowchart of FIG. **10** and a process chart of FIG. **11**. FIG. **10** is the flowchart illustrating the process of the design image retrieval apparatus **1**. FIG. **11** is the process chart illustrating the process of the design image retrieval apparatus **1**.

The objects as the retrieval targets are two (X**1**,X**2**) in the example of FIG. **10** and FIG. **11**. Each object X**1**, X**2** corresponds to six images in six orientation directions. Each object X**1**, X**2** is represented by a cube (hexahedron), and an image is attached to each side of the cube.

In step S**1**, the image feature quantity extraction unit **22** extracts the image feature quantities of all images of the object as a retrieval target, and stores the extracted image feature quantities onto the storage unit **34**.

In step S**2**, the image feature quantity extraction unit **21** extracts the image feature quantities of all images of the object as a search key, and stores the extracted image feature quantities onto the storage unit **33**.

In step S**3**, the similarity calculating unit **23** determines whether all the objects as the retrieval targets on the storage unit **34** have been selected. If objects as retrieval targets remain to be selected on the storage unit **34**, the similarity calculating unit **23** selects the object X**1** from the unselected objects as the retrieval targets on the storage unit **34**, and proceeds to step S**4**. If it is determined in step S**3** that all the objects as the retrieval targets have been selected on the storage unit **34**, processing proceeds to step S**11**.

In step S**4**, the similarity calculating unit **23** determines whether all the images of the object X**1** selected in step S**3** have been selected. If there remain images of the object X**1** to be selected, the similarity calculating unit **23** selects an unselected image of the object X**1**, and proceeds to step S**5**. If it is determined in step S**4** that all the images have been selected, processing proceeds to step S**9**.

In step S**5**, the similarity calculating unit **23** sets the image of the object X**1** selected in step S**4** to be Y**1**. Processing proceeds to step S**6**. The similarity calculating unit **23** determines whether all the images of the object as the search key have been selected. If any image of the object as the search key remains to be selected, the similarity calculating unit **23** selects the unselected image of the object as the search key, and processing proceeds to step S**7**. If all the images of the object as the search key have been selected, processing returns to step S**4**.

In step S**7**, the similarity calculating unit **23** sets the image of the object as the search key selected in step S**6** (selected image of the search key) to be Q**1**. The image Q**1** has an image orientation as a plan view. Image Q**2**-Q**6** to be described hereinbelow have image orientations as a bottom view, a front view, a rear view, a right-side view, and a left-side view, respectively. Similarly, images Y**1**-Y**6** to be described hereinbelow have image orientations as a plan view, a bottom view, a front view, a rear view, a right-side view, and a left-side view, respectively.

In step S**8**, the similarity calculating unit **23** calculates a similarity d(Y**1**,Q**1**) between the image Y**1** of the object X**1** and the selected image Q**1** of the search key, based on the image feature quantity of the image Y**1** extracted in step S**1** and the image feature quantity of the selected image Q**1** extracted in step S**2** as previously described.

The similarity calculating unit **23** repeats steps S**6**-S**8** until the similarity calculating unit **23** determines that all the images of the object as the search key have been selected. The

similarity calculating unit **23** thus calculates similarities d(Y**1**,Q**2**)−d(Y**1**,Q**6**) between the image Y**1** of the object X**1** and each of the selected images Q**2**-Q**6** of the search key.

If it is determined that all the images of the object as the search key have been selected, the similarity calculating unit **23** returns from step S**6** to step S**4**. The similarity calculating unit **23** repeats steps S**4**-S**8** until the similarity calculating unit **23** determines that all the images of the object X**1** selected in step S**3** have been selected. The similarity calculating unit **23** thus calculates similarities d(Y**2**,Q**1**)−d(Y**6**, Q**6**) between each of the images Y**2**-Y**6** of the object X**1** and each of the selected images Q**1**-Q**6** of the search key.

Through the process performed heretofore, the similarity calculating unit **23** can produce a table **200** as illustrated in FIG. **11**. If it is determined that all the images of the object X**1** selected in step S**3** have been selected, the similarity calculating unit **23** proceeds from step S**4** to step S**9**. Using the table **200**, the similarity calculating unit **23** determines a correspondence relationship T of the images Y**1**-Y**6** of the object X**1** and the selected images Q**1**-Q**6** of the search key in the descending order of similarity d(YQ).

The similarity calculating unit **23** determines the correspondence relationship T based on the table **200**. In the correspondence relationship T, the selected image Q**1** of the search key corresponds to the image Y**1** of the object X**1**, the selected image Q**2** of the search key corresponds to the image Y**2** of the object X**1**, the selected image Q**3** of the search key corresponds to the image Y**3** of the object X**1**, the selected image Q**4** of the search key corresponds to the image Y**4** of the object X**1**, the selected image Q**5** of the search key corresponds to the image Y**5** of the object X**1**, and the selected image Q**6** of the search key corresponds to the image Y**6** of the object X**1**.

In step S**10**, the similarity calculating unit **23** determines the sum of the similarities d(YQ) mapped by the correspondence relationship T, and sets the sum to be a similarity D(X**1**) between the object X**1** and the object of the search key. In the table **200** of FIG. **11**, the similarity D(X**1**) is 81.

Processing returns from step S**10** to step S**3** as depicted in FIG. **10**. The similarity calculating unit **23** determines whether all the objects as the retrieval targets on the storage unit **34** have been selected. In the embodiment, there remains an object as a retrieval target on the storage unit **34**, and the similarity calculating unit **23** selects an unselected object X**2** as a retrieval target on the storage unit **34**.

The similarity calculating unit **23** performs steps S**4**-S**8** on the object X**2** as a retrieval target, thereby producing a table **201** as illustrated in FIG. **11**. If it is determined that all the images of the object X**2** selected in S**3** have been selected, the similarity calculating unit **23** proceeds from step S**4** to step S**9**. Using the table **201**, the similarity calculating unit **23** determines a correspondence relationship T between each of the images Y**1**-Y**6** of the object X**2** and each of the selected images Y**1**-Y**6** of the retrieval keys in the descending order of similarity d(YQ).

The similarity calculating unit **23** determines the correspondence relationship T based on the table **201**. In the correspondence relationship T, the selected image Q**1** of the search key corresponds to the image Y**1** of the object X**2**, the selected image Q**2** of the search key corresponds to the image Y**2** of the object X**2**, the selected image Q**3** of the search key corresponds to the image Y**3** of the object X**2**, the selected image Q**4** of the search key corresponds to the image Y**4** of the object X**2**, the selected image Q**5** of the search key corresponds to the image Y**6** of the object X**2**, and the selected image Q**6** of the search key corresponds to the image Y**5** of the object X**2**.

In step S**10**, the similarity calculating unit **23** determines the sum of the similarities d(YQ) mapped by the correspondence relationship T, and sets the sum to be a similarity D(X**2**) between the object X**2** and the object of the search key. In the table **201** of FIG. **11**, the similarity D(X**2**) is 75.

Processing returns from step S**10** to step S**3** as depicted in FIG. **10**. The similarity calculating unit **23** determines whether all the objects as the retrieval targets on the storage unit **34** have been selected. In the embodiment, all the objects as the retrieval targets on the storage unit **34** have been selected. The similarity calculating unit **23** proceeds to step S**11** and requests the retrieval result display unit **24** to display the retrieval results. The retrieval result display unit **24** sorts the similarities D(X**1**) and D(X**2**) in the descending order.

The retrieval result display unit **24** sorts the similarities D(X**1**) and D(X**2**) in the descending order, namely, in the order of similarity D(X**1**) and D(X**2**). In this example, the object X**1** is displayed first, and the object X**2** is displayed second since D(X**1**) is greater than D(X**2**).

Processing proceeds to step S**12**. The retrieval result display unit **24** displays the six images (images Y**1**-Y**6**) of each of the objects X**1** and X**2** on the respective sides of the cubes in accordance with the object X**1** and the search key, the object X**2** and the search key, and the respective correspondence relationships T. When the six images (images Y**1**-Y**6**) of each of the objects X**1** and X**2** are displayed on the respective sides of the cubes in accordance with the correspondence relationships T, the retrieval result display unit **24** determines which side of the cube each of the six images is to be displayed on based on the image orientation of the images Q**1**-Q**6** and the correspondence relationship T. For example, as illustrated in FIG. **11**, the retrieval result display unit **24** displays the images with the image Y**5** of the object X**2** interchanged with the image Y**6** of the object X**2**.

When the images Y**1**-Y**6** of the object X**1** as the retrieval targets are displayed on the respective sides of the cube, one of the images Y**1**-Y**6** most similar to the images Q**1**-Q**6** as the search key is attached to the side in the same orientation as the corresponding one of the images Q**1**-Q**6** as the search key.

The cube corresponding to the object X**1** is rotated so that the similar image is attached to the same side on the cube as the corresponding one of the images Q**1**-Q**6** of the search key. The retrieval result display unit **24** then attaches the image second most similar to a corresponding one of the images Q**1**-Q**6** as the search key on the side of the cube in the same orientation as the corresponding one of the images Q**1**-Q**6**. If the image cannot be attached to the side in the same orientation as the corresponding one of the images Q**1**-Q**6** as the search key because of the limitation of the cube, the retrieval result display unit **24** skips that step without attaching the image on the corresponding side. Similarly, the retrieval result display unit **24** then attaches the images third to sixth most similar to the corresponding ones of the images Q**1**-Q**6** as the search key on the side of the cube in the same orientations as the corresponding ones of the images Q**1**-Q**6**.

For example, the most similar image may be the image on the front view of the cube, and a side similar to the images Q**1**-Q**6** as the search key may also be the front view of the cube. In such a case, the retrieval result display unit **24** attaches the first most similar image on the front of the cube.

The second most similar image may be the image on the rear of the cube, and a side similar to the images Q**1**-Q**6** as the search key may be the left-side view of the cube. In such a case, the retrieval result display unit **24** rotates the cube with the image attached first on the front of the cube, and determines whether the second most similar image can be attached on the left side of the cube. It is assumed here that the second

most similar image cannot be attached on the left side. The retrieval result display unit **24** thus skips this step without attaching the second most similar image.

The retrieval result display unit **24** thus repeats the same process as the process performed on the first and second most similar images in order of the third, fourth, fifth, and sixth most similar images to the images Q1-Q6 as the search key. If an image not yet attached onto any side of the cube remains subsequent to the attaching of the sixth most similar image, the retrieval result display unit **24** determines, for the image not yet attached onto any side of the cube, a side on which the image is to be attached within the range satisfying the rotation limitation of the cube.

The retrieval result display unit **24** may display the retrieval result on one of the retrieval result display screens illustrated in FIGS. **12-17** in addition to or instead of the retrieval result display screen **110** of FIG. **9**.

FIG. **12** illustrates a retrieval result display screen **300** based on a cubic diagram. In the example of FIG. **12**, the retrieval result display unit **24** determines one of the six images of each of the objects **302-304** as retrieval targets, which is most similar to an object **301** as a search key, on each of the objects **302-304**. The retrieval result display unit **24** then displays the objects **302-304** as the retrieval targets on the cubic diagrams on a retrieval result display screen **300** in the order of from greatest to least similarity.

FIG. **13** illustrates another retrieval result display screen **310**. In the example of FIG. **13**, the retrieval result display unit **24** determines one of the six images of each of the objects **312-314** as retrieval targets, which is most similar to an object **311** as a search key, on each of the objects **312-314**. The retrieval result display unit **24** then displays the determined images having greater similarity in planar views on a retrieval result display screen **310**.

FIG. **14** illustrates a retrieval result display screen **320** based on a representative view. The retrieval result display unit **24** displays representative views **322-324** of each object as a retrieval target (for example, images depicted at a slant angle to the object as the retrieval target) on a retrieval result display screen **320** in the order of similarity with an object **321** as a search key.

FIG. **15** illustrates a retrieval result display screen with a switching operation performed to switch between a representative view and a cubic diagram. In the example of FIG. **15**, the retrieval result display unit **24** displays representative views **332-334** of an object as a retrieval target on a retrieval result display screen **330** in the order of similarity with an object **331** as a search key. The retrieval result display unit **24** can also display the representative views **332-334** of the object as the retrieval target in cubic diagrams **342-344** on a retrieval result display screen **340** in the order of similarity with an object **341** as a search key. The user selects the retrieval result display screen **330** or the retrieval result display screen **340** by specifying whichever retrieval result display screen **330** or **340** is desired.

FIG. **16** illustrates a retrieval result display screen **350** displaying an image on a side specified on the search key. The side of the cube of an object **351** as a search key is specified when the retrieval result display unit **24** displays objects **352-356** as retrieval targets in the order of similarity with the object **351** as the search key. The images of the objects **352-356** corresponding to (i.e., similar to) the specified side are thus displayed on a retrieval result display screen **350** in the order of similarity.

When the objects **352-356** as the retrieval targets are displayed in the order of similarity with the object **351** as the search key, the user may manually modify the orientation of each of the objects **352-356**, as appropriate, or change the side on which the image is attached, as appropriate.

FIG. **17** illustrates a retrieval result display screen **360** on which partially similar portions are marked in rectangular boxes. In this example, the similarity calculating unit **23** calculates as an image similarity the degree of partial similarity with an image of an object **361** as a search key. The retrieval result display unit **24** attaches and displays the images of objects **362-366** as retrieval targets on cubes. In this case, the retrieval result display unit **24** marks by a rectangular box a portion of each image of the objects **362-366** as the retrieval targets partially similar to the image of the object **361** as the search key.

In accordance with embodiments described herein, one object is displayed in a plurality of images, and retrieval results are displayed in the order of similarity. The design image retrieval apparatus **1** according to embodiments described herein displays the image as the search key with the image of the object as the retrieval target corresponding thereto. The images having a higher similarity are displayed on the same side in the same orientation.

The design image retrieval apparatus **1** of the embodiment also displays the image as the search key and the image of the object as the retrieval target so that the images having higher similarities are placed on the sides in the same orientation in order. The user can thus verify easily the retrieval results.

Embodiments discussed herein may relate to the use of a computer including various computer hardware or software units. Embodiments also include computer-readable storage media that store programs for causing computers to perform processes discussed herein. The computer-readable storage media can be any available or suitable media that can be accessed by a computer. For example, such computer-readable storage media can include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, solid-state devices, or any other storage medium which can be used to carry or store desired program code in the form of computer-executable instructions or data structures and can be accessed by a computer.

Programs and computer-executable instructions include, for example, instructions and data which cause a general-purpose computer, special-purpose computer, or special purpose processing device to perform a function or group of functions. A computer, as used herein, can include one or more computers or processors that may be local, remote or distributed with respect to one another, or can include computer or processor subsystems.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present inventions have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. An image retrieval method of a computer for retrieving similar objects, comprising:

reading from a first database a plurality of images of an image group mapped to a multidimensional object as a retrieval target, and extracting an image feature quantity of the read plurality of images, the first database storing

the plurality of images depicting the multidimensional object as the retrieval target from a plurality of orthoprojection viewpoints of the multidimensional object in different directions;

reading from a second database a plurality of images of an image group mapped to a multidimensional object as a search key, and extracting an image feature quantity of the read plurality of images, the second database storing the plurality of images depicting the multi-dimensional object as the search key from a plurality of orthoprojection viewpoints in different directions;

determining a similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, based on the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the search key; and

displaying, on an output device, as retrieval results the plurality of images of the image group mapped to the multidimensional object as the retrieval target in an order of similarity of the multidimensional object as the retrieval target based on the determined similarity,

wherein the retrieval results are presented by displaying the multidimensional object as the search key in a cubic diagram using the plurality of images of the multidimensional object as the search key, and by displaying the multidimensional object as the retrieval target in another cubic diagram using the plurality of images of the multidimensional object as the retrieval target.

2. The image retrieval method according to claim **1**, wherein the retrieval results are presented by determining a correspondence relationship representing a similarity between an image resulting from depicting the multidimensional object as the search key from one orthoprojection viewpoint in one direction and an image resulting from depicting the multidimensional object as the retrieval target from another orthoprojection viewpoint in another direction, based on the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the search key, and by rearranging and displaying the plurality of images of the multidimensional object as the retrieval target in accordance with the correspondence relationship so that the plurality of images of the multidimensional object as the retrieval target are similar to the plurality of images of the multidimensional object as the search key.

3. The image retrieval method according to claim **1**, wherein the cubic diagram of the multidimensional object as the retrieval target is configured to be rotated in synchronization with and in the same direction as the cubic diagram of the multidimensional object as the search key.

4. The image retrieval method according to claim **1**, wherein in order to determine the similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multidimensional object as the retrieval target are calculated in terms of similarity, a correspondence relationship of the images providing the maximum sum of the similarities is determined, and the mean value of the similarities of the images in the correspondence relationship providing the maximum sum of the similarities is set to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

5. The image retrieval method according to claim **1**, wherein in order to determine the similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multidimensional object as the retrieval target are calculated in terms of similarity, a correspondence relationship of the images providing the maximum sum of the similarities is determined, and the maximum similarity of the images in the correspondence relationship providing the maximum sum of the similarities is set to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

6. An image retrieval apparatus, comprising:

a memory; and

a processor that executes a procedure in the memory, the procedure including:

a first image feature extracting process configured to read from a first database a plurality of images of an image group mapped to a multidimensional object as a retrieval target, and extracting an image feature quantity of the read plurality of images, the first database storing the plurality of images depicting the multi-dimensional object as the retrieval target from a plurality of orthoprojection viewpoints in different directions;

a second image feature extracting process configured to read from a second database a plurality of images of an image group mapped to a multi-dimensional object as a search key, and extracting an image feature quantity of the read plurality of images, the second database storing the plurality of images depicting the multi-dimensional object as the search key from a plurality of orthoprojection viewpoints in different directions;

a similarity calculating process configured to calculate a similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, based on the image feature quantity of the multidimensional object as the retrieval target and the image feature quantity of the multidimensional object as the search key; and

a retrieval result displaying process configured to display, on an output device, as retrieval results the plurality of images of the image group mapped to the multidimensional object as the retrieval target in the order of similarity of the multidimensional object as the retrieval target based on the similarity,

wherein the retrieval results are presented by displaying the multidimensional object as the search key in a cubic diagram using the plurality of images of the multidimensional object as the search key, and by displaying the multidimensional object as the retrieval target in another cubic diagram using the plurality of images of the multidimensional object as the retrieval target.

7. The image retrieval apparatus according to claim **6**, wherein the retrieval result displaying process determines a correspondence relationship representing a similarity

between an image resulting from depicting the multidimensional object as the search key from one orthoprojection viewpoint in one direction and an image resulting from depicting the multidimensional object as the retrieval target from another orthoprojection viewpoint in another direction, based on the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the search key, and rearranges and displays the plurality of images of the multidimensional object as the retrieval target in accordance with the correspondence relationship so that the plurality of images of the multidimensional object as the retrieval target are similar to the plurality of images of the multidimensional object as the search key.

8. The image retrieval apparatus according to claim **6**, wherein the retrieval result display process is configured to rotate the cubic diagram of the multidimensional object as the retrieval target in synchronization with and in the same direction as the cubic diagram of the multidimensional object as the search key.

9. The image retrieval apparatus according to claim **6**, wherein the similarity calculating process calculates similarities of all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multidimensional object as the retrieval target, determines a correspondence relationship of the images providing the maximum sum of the similarities, and sets the mean value of the similarities of the images in the correspondence relationship providing the maximum sum of the similarities to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

10. The image retrieval apparatus according to claim **6**, wherein the similarity calculating process calculates similarities of all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multidimensional object as the retrieval target, determines a correspondence relationship of the images providing the maximum sum of the similarities, and sets the maximum similarity of the images in the correspondence relationship providing the maximum sum of the similarities to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

11. A non-transitory computer-readable storage medium that stores a program causing a computer to perform a process of retrieving similar multidimensional objects, the process comprising:

reading from a first database a plurality of images of an image group mapped to a multidimensional object as a retrieval target, and extracting an image feature quantity of the read plurality of images, the first database storing the plurality of images depicting the multi-dimensional object as the retrieval target from a plurality of orthoprojection viewpoints in different directions;

reading from a second database a plurality of images of an image group mapped to a multidimensional object as a search key, and extracting an image feature quantity of the read plurality of images, the second database storing the plurality of images depicting the multi-dimensional object as the search key from a plurality of orthoprojection viewpoints in different directions;

determining a similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, based on the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the search key; and

displaying, on an output device, as retrieval results, the plurality of images of the image group mapped to the multidimensional object as the retrieval target in the order of similarity of the multidimensional object as the retrieval target based on the determined similarity,

wherein the retrieval results are presented by displaying the multidimensional object as the search key in a cubic diagram using the plurality of images of the multidimensional object as the search key, and by displaying the multidimensional object as the retrieval target in another cubic diagram using the plurality of images of the multidimensional object as the retrieval target.

12. The non-transitory computer-readable storage medium according to claim **11**, wherein the retrieval results are presented by determining a correspondence relationship representing a similarity between an image resulting from depicting the multidimensional object as the search key from one orthoprojection viewpoint in one direction and an image resulting from depicting the multidimensional object as the retrieval target from another orthoprojection viewpoint in another direction, based on the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the retrieval target and the image feature quantity of the plurality of images of the image group mapped to the multidimensional object as the search key, and by rearranging and displaying the plurality of images of the multidimensional object as the retrieval target in accordance with the correspondence relationship so that the plurality of images of the multidimensional object as the retrieval target are similar to the plurality of images of the multidimensional object as the search key.

13. The non-transitory computer-readable storage medium according to claim **11**, wherein the cubic diagram of the multidimensional object as the retrieval target is rotated in synchronization with and in the same direction as the cubic diagram of the multidimensional object as the search key.

14. The non-transitory computer-readable storage medium according to claim **11**, wherein in order to determine the similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multidimensional object as the retrieval target are calculated in terms of similarity, a correspondence relationship of the images providing the maximum sum of the similarities is determined, and the mean value of the similarities of the images in the correspondence relationship providing the maximum sum of the similarities is set to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

15. The non-transitory computer-readable storage medium according to claim **11**, wherein in order to determine the similarity between the image group mapped to the multidimensional object as the search key and the image group mapped to the multidimensional object as the retrieval target, all combinations of each of the images of the image group mapped to the multidimensional object as the search key and each of the images of the image group mapped to the multi-

dimensional object as the retrieval target are calculated in terms of similarity, a correspondence relationship of the images providing the maximum sum of the similarities is determined, and the maximum similarity of the images in the correspondence relationship providing the maximum sum of the similarities is set to be a similarity between the multidimensional object as the retrieval target and the multidimensional object as the search key.

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